line. Approximately 900 areas in Parcel E and E-2 were noted during the survey that exceeded twice the background gamma radiation levels; the highest measurements were identified in the area known as the "metal reef" within Parcel E. Samples collected from those locations identified ^{226}Ra as the contaminant.

3.1.6. Phase V Radiological Investigation (2002 to 2003)

The Phase V radiological investigation began in January 2002 prior to issuance of the HRA. The purpose was to support the release of buildings or areas that had been identified as areas where radioactive materials had been used or areas where previous removal actions to remove known contamination had occurred. The Phase V investigation of what is now Parcel E-2 was performed in 2002 and 2003, and the results were not available for inclusion in the HPS HRA (NAVSEA, 2004); therefore, the Phase V investigation results are presented for the first time in this radiological addendum. The scoping survey was of the surface only and was designed to meet the requirements of a Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) Class 1 Final Status Survey if contamination was not found (U.S. Department of Defense et al., 2000). The object of the Phase V investigation at Parcel E-2 was to demonstrate whether residual radioactivity on the surface met the predetermined release criterion as summarized below.

- ^{226}Ra: 1 picocurie per gram (pCi/g) greater than background not to exceed 2 pCi/g[5]
- ^{90}Sr: 10.8 pCi/g
- ^{137}Cs: 0.13 pCi/g[6]
- ^{60}Co: 0.060 pCi/g

These release criteria were considered equivalent to EPA preliminary remediation goals (PRGs) for outdoor worker exposure to soil, based on agreements with EPA. For ^{226}Ra and ^{137}Cs, the outdoor worker release criteria are identical to the release criteria for future residents. In contrast, the outdoor worker release criterion for ^{90}Sr (10.8 pCi/g) is greater than the residential release criterion (0.331 pCi/g). Similarly, the outdoor worker release criterion for ^{60}Co (0.0602 pCi/g) is greater than the residential release criterion (0.0361 pCi/g).

The investigation area was divided into 73 Class 1 survey units measuring 40 by 50 meters (2,000 square meters, or 21,528 square feet) each. Each survey unit was assigned an alphabetic designation. Sixteen systematic sample locations were established in each grid approximately 11 meters apart. Figure 5 provides a layout of the survey units and the systematic sample locations. Reference (background) readings consisted of 16 1-minute static gamma readings taken on the hillside of Parcel A and 16 samples collected at various areas within Parcels B, C, D, and E.

[5] The ^{226}Ra release criterion was 5 pCi/g when the Phase V investigation was started but was subsequently reduced to 1 pCi/g above background; the uncertainty related to this change in criterion is discussed in Section 7.3.

[6] The ^{137}Cs release criterion applied to this survey when conducted in 2002 is slightly higher than the one used today (0.113 pCi/g); however, this change does not directly impact the results of this survey.

The Phase V investigation consisted of the following steps:

- Gamma scans of 100 percent of the surface area
- Sixteen systematic static gamma measurements in each survey unit
- Biased static measurements in areas where high gamma readings were measured
- Exposure rate measurements from the systematic static measurement locations
- Collection of soil samples at static and biased measurement locations
- Analysis of the soil samples by gamma spectroscopy at the on-site laboratory to quantify activity levels of a suite of 17 radionuclides, including ^{137}Cs and ^{226}Ra

A total of 1,168 systematic and 24 biased soil samples were collected during the Phase V investigation. Gamma scan measurements typically ranged from 4,500 to 8,000 cpm, with occasional scan measurements identified as being in excess of 10,000 cpm. Sample results identified residual radioactivity exceeding the release criteria for ^{137}Cs and ^{226}Ra in each survey unit. The elevated levels appeared to be consistent over the surface of the area, including the landfill cap, and there is a direct correlation between gamma static readings and gamma spectroscopy results. Results for samples from the reference areas indicated mean background activity level of 0.049 pCi/g for ^{137}Cs and 0.82 pCi/g for ^{226}Ra. These background activity levels are consistent with the background activity levels used for the interim removal actions at Parcels E and E-2 (TtECI, 2007a, 2007b, and 2007c). The analytical results from the systematic and biased soil samples are provided in Table A-2 of Appendix A, and the complete laboratory reports for the Phase V investigation are provided as an attachment to Appendix A. Figures 6 and 7 show the sample locations across Parcel E-2 where ^{226}Ra and ^{137}Cs exceeded the release criteria (1.82 pCi/g for ^{226}Ra and 0.113 pCi/g for ^{137}Cs; as stated previously, these release criteria are identical for outdoor worker and residential exposure scenarios). Figure 8 shows the sample locations where ^{60}Co exceeded the residential release criterion (0.0361 pCi/g; the outdoor worker release criterion is 0.0602 pCi/g). Only the Phase V survey units in the vicinity of the Experimental Ship-Shielding Area are presented on Figure 8, because ^{60}Co was the only ROC in this area of Parcel E-2.

Based on the sample results, every survey unit had activity levels of ^{226}Ra exceeding the release criterion and 46 of the survey units had activity levels of ^{137}Cs exceeding the release criterion. All of the eight survey units within the vicinity of the Experimental Ship-Shielding Area had activity levels of ^{60}Co exceeding the residential release criterion; however, only three of the eight survey units had activity levels of ^{60}Co exceeding the outdoor worker release criterion. Ten percent of the samples were sent to an off-site laboratory for quality assurance and ^{90}Sr analysis because the on-site laboratory did not analyze directly for ^{90}Sr. Results from the quality assurance laboratory were within the range of results from the on-site laboratory (based on a normal distribution of results). The average ratio of ^{90}Sr to ^{137}Cs results

Table A-1. Soil Gamma Spectroscopy Results for Phase I Radiological Investigation at Parcel E-2, Hunters Point Shipyard, San Francisco, California

All results in picocuries per gram (pCi/g); all samples collected within 6 inches of the ground surface

Sample ID	IR Site	Phase V Grid	^{241}Am	Std_Dev	^{137}Cs	Std_Dev	^{40}K	Std_Dev	^{226}Ra	Std_Dev	^{228}Ra	Std_Dev	^{228}Th	Std_Dev	^{239}Pu/^{240}Pu	Std_Dev	^{238}Pu	Std_Dev
NAI2048	IR-02	Removed	<0.10		<0.071		13.9	1.6	0.58	0.18	0.82	0.29	0.74	0.26				
NAI2049	IR-02	Removed	<0.09		0.11	0.13	11.0	1.7	2.01	0.24	0.56	0.33	0.48	0.22				
NAI2055	IR-01/21	ABM	<0.16		<0.11		11.5	1.4	0.76	0.18	1.40	0.31	1.16	0.24	<0.017		<0.027	
NAI2056	IR-01/21	AIL	<0.13		<0.10		8.5	1.2	0.60	0.12	0.73	0.27	0.69	0.22				
NAI2059	IR-01/21	None	<0.12		0.074	0.071	10.11	1.3	0.43	0.12	0.39	0.21	0.44	0.17				
NAI2060	IR-01/21	None	<0.14		<0.12		10.3	1.5	0.52	0.16	0.89	0.35	1.05	0.23				
NAI2061	IR-01/21	AAB	<0.12		<0.099		5.7	1	0.54	0.12	0.82	0.22	0.68	0.24				
NAI2062	IR-01/21	ABA	<0.14		<0.10		8.5	1.2	0.53	0.16	0.69	0.26	0.80	0.14				
NAI2063	IR-01/21	ABB	<0.14		0.20	0.1	8.6	1.2	0.68	0.13	0.72	0.31	0.62	0.23				
NAI2064	IR-01/21	AAC	<0.16		<0.12		9.9	1.4	0.76	0.17	0.78	0.34	1.04	0.27	<0.017		0.033	0.011
NAI2065	IR-01/21	ABH	<0.14		0.114	0.081	7.9	1.2	0.49	0.14	0.78	0.3	0.69	0.21				
NAI2066	IR-01/21	ADI	<0.11		<0.11		19.5	1.6	0.14	0.11	0.35	0.18	0.36	0.18				
NAI2067	IR-01/21	ADJ	<0.13		<0.12		10.2	1.5	0.46	0.15	0.62	0.26	0.67	0.23				
NAI2068	IR-01/21	ACL	<0.14		0.040	0.068	17.7	1.5	0.64	0.15	1.02	0.34	0.87	0.23				
NAI2069	IR-01/21	AEM	<0.12		0.13	0.1	5.1	1.3	0.34	0.17	0.42	0.31	0.48	0.22				
NAI2071	IR-01/21	AGK	<0.09		<0.096		<1.2		<0.08		<0.18		<0.12					
NAI2072	IR-01/21	Removed	<0.17		<0.16		10.3	1.8	0.52	0.17	0.33	0.3	0.25	0.22				
NAI2080	IR-01/21	ABE	<0.20		<0.084		21.8	2.2	0.36	0.16	0.85	0.45	0.64	0.32				
NAI2081	IR-01/21	ACH	<0.16		<0.080		8.6	1.5	0.55	0.2	0.35	0.36	0.64	0.37				
NAI2082	IR-01/21	ABJ	<0.19		<0.069		12.4	1.7	0.59	0.24	1.31	0.4	0.69	0.32				
NAI2083	IR-01/21	AHI	<0.16		0.087	0.096	1.6	1.5	0.25	0.16	1.42	0.68	0.47	0.37				
NAI2084	IR-01/21	AIL	<0.16		<0.075		8.0	1.4	0.46	0.17	0.93	0.5	0.51	0.24				
NAI2100	IR-01/21	AFK	<0.13		<0.055		8.9	1.3	0.72	0.14	1.25	0.34	1.00	0.23				
NAI2101	IR-02	None	<0.10		<0.053		8.2	1	0.27	0.12	0.26	0.25	<0.17					
NAI2115	IR-01/21	AAA	<0.31		<0.089		5.5	1.4	0.57	0.16	1.10	0.42	0.90	0.31	<0.015		0.034	0.026
NAI2116	IR-01/21	ABB	<0.34		0.071	0.064	8.9	1.5	0.90	0.18	1.55	0.38	1.28	0.31	<0.015		0.117	0.046
NAI2117	IR-01/21	ABC	<0.15		0.107	0.063	9.0	1.3	0.51	0.16	0.73	0.26	0.82	0.28	<0.014		0.051	0.034
NAI2118	IR-01/21	Removed	<2.9		<47		14.5	7.9	454.6	2.9	<2.5		<1.6					
Summary Statistics																		
Number of Analyses			28		28		28		28		28		28		5		5	
Number of Detections			0		9		27		27		26		25		0		4	
Minimum Detected Activity			NA		0.04		1.6		0.14		0.26		0.25		NA		0.033	
Maximum Detected Activity			NA		0.2		21.8		454.6		1.55		1.28		NA		0.117	
Residential Release Criterion			1.36		0.113		--[a]		1.63		0.289		23.4		2.59		2.95	
Exceedances of Residential Criterion			0		3		--[a]		2		25		0		0		0	
Outdoor Worker Release Criterion			5.67		0.113		--[a]		1.63		NA		962		14		558	
Exceedances of Outdoor Worker Criterion			0		3		--[a]		2		NA		0		0		0	
Background Data																		
NAI2001	Background		<0.31		0.134	0.083	8.1	1.7	0.48	0.19	0.77	0.4	0.71	0.27				
NAI2002	Background		<0.31		0.155	0.087	10.5	2.1	0.34	0.18	1.05	0.52	0.66	0.37				
NAI2003	Background		<0.12		0.229	0.064	4.82	0.87	0.62	0.13	1.25	0.31	0.99	0.2				
NAI2004	Background		<0.41		0.38	0.15	12	2.4	1.05	0.27	1.51	0.55	1.36	0.42				
NAI2005	Background		<0.23		<0.073		1.5	1.4	<0.11		<0.29		<0.21					
NAI2006	Background		<0.30		<0.075		20.1	2.4	0.5	0.16	0.71	0.39	0.65	0.3				
NAI2007	Background		<0.33		0.109	0.076	9.7	1.9	0.88	0.22	0.62	0.38	0.74	0.42				
NAI2008	Background		<0.39		<0.079		14	2.2	1.13	0.25	1.44	0.46	1.36	0.47				
Average Background Concentration					0.14				0.63									

Table A-1. Soil Gamma Spectroscopy Results for Phase I Radiological Investigation at Parcel E-2, Hunters Point Shipyard, San Francisco, California

Notes:
Data compiled from "Surface Confirmation Radiation Survey Draft Report, Naval Station Treasure Island, Hunters Point Annex, San Francisco, California," November 3, 1992
Only data from Parcel E-2 and reference (background) site are presented in this table.
Data for all radionuclides analyzed are presented for information purposes only; ^{137}Cs and ^{226}Ra are the only ROCs at Parcel E-2 that were analyzed as part of the Phase I investigation.
a ^{40}K is a naturally occurring radionuclide and was reported at a range of 1.5 to 20.1 pCi/g in background samples collected during the Phase I investigation. Furthermore, background activity levels of ^{40}K typically range from 3 to 30 pCi/g (EPA, 1995). Consequently, ^{40}K is not a radionuclide of concern at Hunters Point Shipyard.

^{241}Am = americium-241
^{137}Cs = cesium-137
^{40}K = potassium-40
^{238}Pu = plutonium-238
^{239}Pu = plutonium-239
^{240}Pu = plutonium-240
^{226}Ra = radium-226
^{228}Ra = radium-228
^{228}Th = thorium-228

< = not detected above MDA
IR = Installation Restoration
MDA = minimum detectable activity
NA = not available
pCi/g = picocuries per gram
Std_Dev = standard deviation

Table A-2. Soil Gamma Spectroscopy Results for Phase V Radiological Investigation at Parcel E-2, Hunters Point Shipyard, San Francisco, California

Grid	Sample Number	Date	Time	Results[1] ^{137}Cs	Results[1] ^{90}Sr[2]	Results[1] ^{226}Ra
AAA	1	9/10/2002	7:00:00	0.075	0.273	1.083
	2	9/10/2002	7:05:00	**0.115**	0.417	**2.712**
	3	9/10/2002	7:10:00	**0.154**	0.558	0.704
	4	9/10/2002	7:15:00	**0.116**	0.421	1.148
	5	9/10/2002	7:20:00	0.108	0.392	**2.080**
	6	9/10/2002	7:25:00	0.064	0.232	**2.691**
	7	9/10/2002	7:30:00	0.080	0.290	**2.888**
	8	9/10/2002	7:35:00	0.087	0.315	1.557
	9	9/10/2002	7:40:00	0.094	0.341	**3.135**
	10	9/10/2002	7:45:00	0.091	0.330	0.430
	11	9/10/2002	7:50:00	0.051	0.185	**2.497**
	12	9/10/2002	7:55:00	**0.121**	0.439	**2.746**
	13	9/10/2002	8:00:00	0.048	0.174	**2.619**
	14	9/10/2002	8:05:00	0.107	0.388	**2.968**
	15	9/10/2002	8:10:00	0.087	0.315	**2.237**
	16	9/10/2002	8:15:00	0.109	0.395	**2.257**
	17	7/31/2002	10:30:00	0.064	0.232	1.535
	18	7/31/2002	10:40:00	0.100	0.363	1.651
	19	7/31/2002	10:48:00	0.020	0.072	1.667
			Mean	0.089	0.323	2.032
AAB	1	8/29/2002	10:30:00	0.078	0.283	1.385
	2	8/29/2002	10:35:00	0.104	0.377	**2.348**
	3	8/29/2002	10:40:00	0.081	0.294	**2.772**
	4	8/29/2002	10:45:00	0.030	0.109	**2.193**
	5	8/29/2002	10:50:00	0.082	0.297	1.883
	6	8/29/2002	11:25:00	0.074	0.268	**2.214**
	7	8/29/2002	11:00:00	**0.405**	1.468	**2.235**
	8	8/29/2002	11:05:00	0.101	0.366	1.441
	9	8/29/2002	11:10:00	0.026	0.094	1.911
	10	8/29/2002	11:15:00	0.096	0.348	1.405
	11	8/29/2002	11:20:00	0.020	0.073	0.960
	12	8/29/2002	11:25:00	0.047	0.170	1.374
	13	8/29/2002	11:30:00	0.054	0.196	1.925
	14	8/29/2002	11:35:00	0.047	0.170	**2.515**
	15	8/29/2002	11:40:00	0.061	0.221	1.164
	16	8/29/2002	11:45:00	**0.138**	0.500	**2.652**
			Mean	0.090	0.327	1.902

Grid	Net Results[3] ^{137}Cs	Net Results[3] ^{90}Sr	Net Results[3] ^{226}Ra
AAA	0.040	0.147	1.214
AAB	0.042	0.151	1.084
AAC	0.028	0.101	1.386
AAD	0.115	0.418	1.301
AAE	0.069	0.249	1.260
AAF	0.065	0.236	1.405
AAG	0.035	0.127	1.020
AAH	0.084	0.306	1.458
AAI	0.062	0.223	1.399
AAJ	0.026	0.096	1.442
AAK	0.009	0.033	1.050
AAL	0.027	0.096	1.653

Net Results for Grid[3]

^{137}Cs	^{90}Sr[2]	^{226}Ra
0.040	0.147	1.214

Net Results for Grid[3]

^{137}Cs	^{90}Sr[2]	^{226}Ra
0.042	0.151	1.084

Reference Area	Sample Number	Date	Time	Results[1] ^{137}Cs	Results[1] ^{90}Sr[2]	Results[1] ^{226}Ra
	1	3/27/2002	13:25:00	0.077	0.279	0.506
	2	3/28/2002	7:05:00	0.027	0.098	1.303
	3	3/4/2002	10:00:00	0.041	0.149	0.519
	4	3/28/2002	8:40:00	0.045	0.163	0.714
	5	3/28/2002	10:45:00	0.016	0.058	0.462
	6	3/28/2002	11:15:00	0.042	0.152	1.058
	7	3/28/2002	11:25:00	0.017	0.062	0.482
	8	3/27/2002	12:35:00	0.065	0.236	0.711
	9	3/28/2002	13:00:00	0.023	0.083	0.990
	10	3/28/2002	13:10:00	0.050	0.181	0.819
	11	3/28/2002	13:15:00	0.071	0.257	0.934
	12	3/28/2002	13:20:00	0.073	0.265	0.678
	13	3/29/2002	7:30:00	0.072	0.261	0.836
	14	3/29/2002	7:45:00	0.068	0.247	1.366
	15	3/29/2002	7:50:00	0.064	0.232	0.795
	16	3/29/2002	11:00:00	0.026	0.094	0.887
			Mean	0.049	0.176	0.818

Notes:

[1] Analytical results for ^{137}Cs and ^{226}Ra from on-site laboratory

[2] 10 percent of samples were analyzed by off-site laboratory for ^{137}Cs, ^{90}Sr, and ^{226}Ra; ratio of ^{90}Sr to ^{137}Cs results from off-site laboratory was used to estimate ^{90}Sr concentrations for the 90 percent of the samples that were not analyzed directly for ^{90}Sr.

[3] Net results present the mean concentrations for each grid less the mean background concentration (from reference area).

Sample numbers 1 through 16 in each grid represent the systematic soil samples; sample numbers greater than 16 represent biased soil samples (many of which were associated with point source anomalies)

Sample results shown in **bold text** exceed the release criterion

All sample results are in picocuries per gram (pCi/g)

< Sample result was below minimum detectable activity